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IPIX

IMAGING VIGNETTE

Transcatheter Caval Valve Implantation Using Multimodality Imaging

Roles of TEE, CT, and 3D Printing

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THIS IPIX ILLUSTRATES 3-DIMENSIONAL (3D) PRINTING GUIDED PERIPROCEDURAL, MULTIMODALITY PICTORIAL PLANNING performed for a successful transcatheter caval valve implantation (CAVI). A 57-year-old patient with severe mitral valve regurgitation status post-mitral ring placement in 2001 (28-mm Cosgrove, Edwards Lifesciences Corp., Irvine, California) and Hodgkin's lymphoma treated with mantle radiation therapy had done well for several years before the development of abdominal distention and lower extremity edema. She had recurrent hospitalizations for abdominal ascites requiring large-volume paracentesis. Two-dimensional echocardiography showed a structurally normal tricuspid valve with severe tricuspid regurgitation and mildly reduced right ventricular systolic function. The patient was evaluated for isolated tricuspid valve surgery and heart transplantation, which were ultimately deemed a prohibitive surgical risk given the history of chest radiation, and she was referred for CAVI.

Pre-CAVI imaging is performed with contrast-enhanced, retrospectively electrocardiogram-gated computed tomography angiography acquisition, extending from the lower chest through the abdomen for dynamic evaluation of the extent of tricuspid regurgitation into the inferior vena cava (IVC). CAVI sizing is performed in the right atrium (RA)–IVC plane (Online Table 1) and at the level of the first hepatic vein (**Figure 1**). 3D printing the RA-IVC topography aids in transcatheter valve selection (**Figure 1**). CT-generated fluoroscopic images (**Figure 2**, Online Video 1) guided the deployment of a 30-mm self-expanding Cook Z-stent (Cook Medical Inc., Bloomington, Indiana) within the RA-IVC junction to prepare a landing zone for the 29-mm SAPIEN XT valve (Edwards Lifesciences Corp., Irvine, California). During deployment, the 30-mm stent migrated superiorly. A second 30-mm stent was deployed lower in the IVC to anchor the scaffolding before advancing the SAPIEN XT into position. Intraprocedural transesophageal echocardiography (TEE) surveyed the right atrium for periprocedural complications (**Figure 3**, Online Video 2). Post-procedure gated CTA of the abdomen, and 2D echocardiogram were performed to evaluate the function and positioning of the CAVI (**Figure 3**, Online Video 3).

The patient was discharged 1 week post-procedure after an uncomplicated hospital stay. She subsequently had 2 repeat admissions for pleural effusions. Four-month follow-up demonstrated no recurrence of ascites or edema, with a decrease in hepatomegaly and only small pleural effusion (**Figure 4**).

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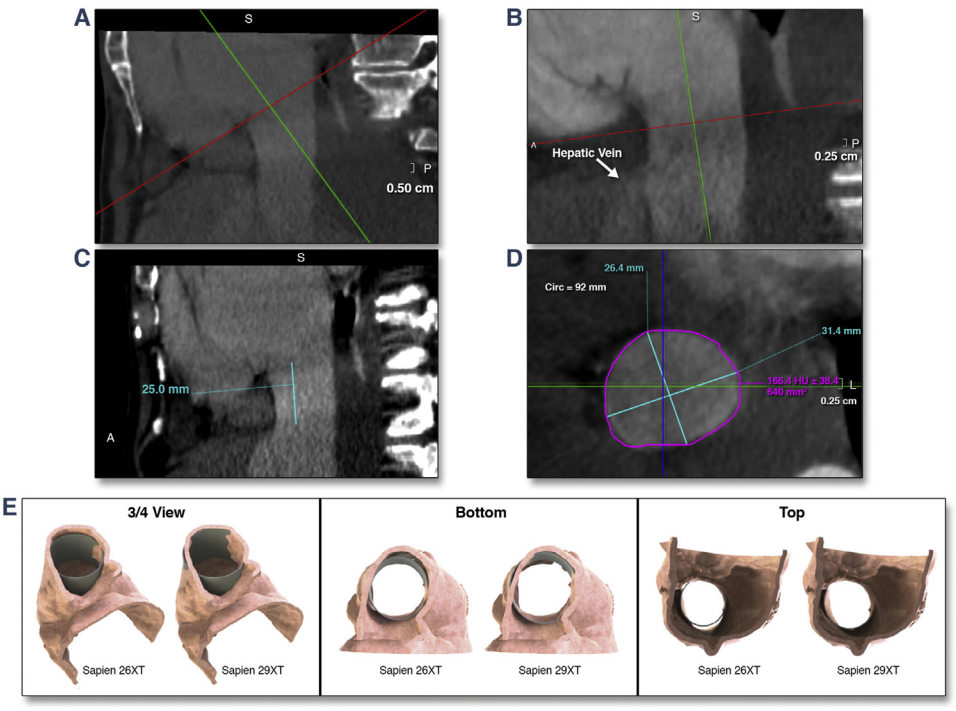
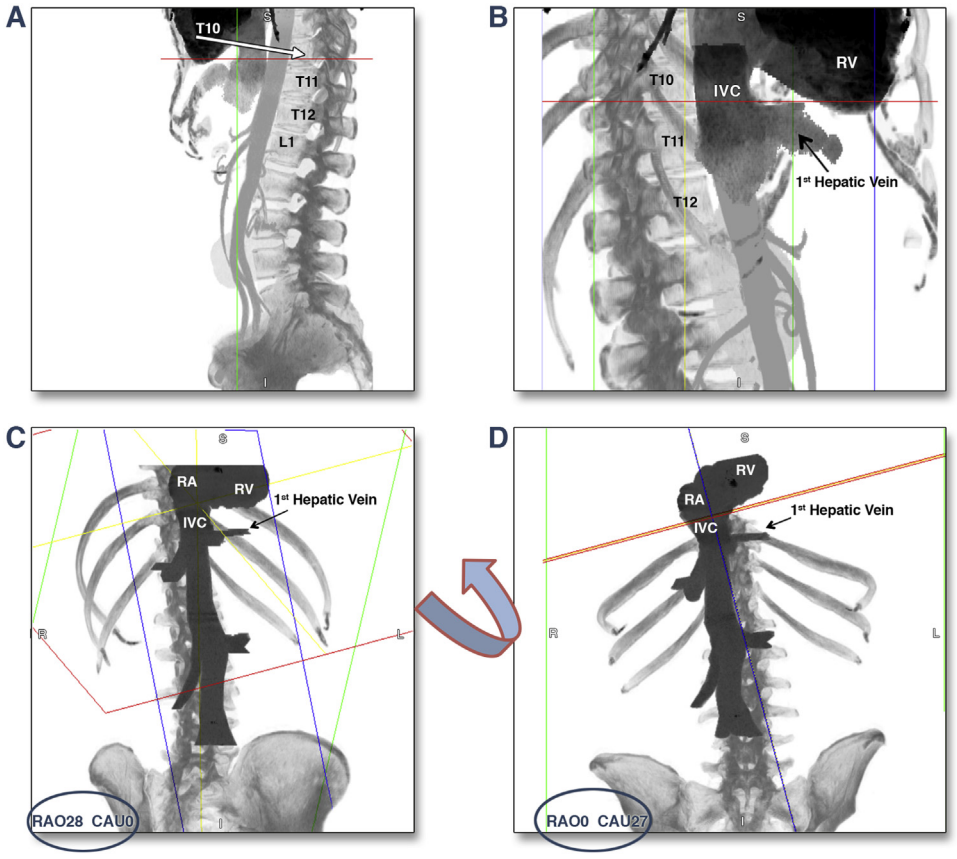
FIGURE 1 Computed Tomography and 3D Print Guided Selection of the SAPIEN 29XT Valve for Caval Valve Implantation



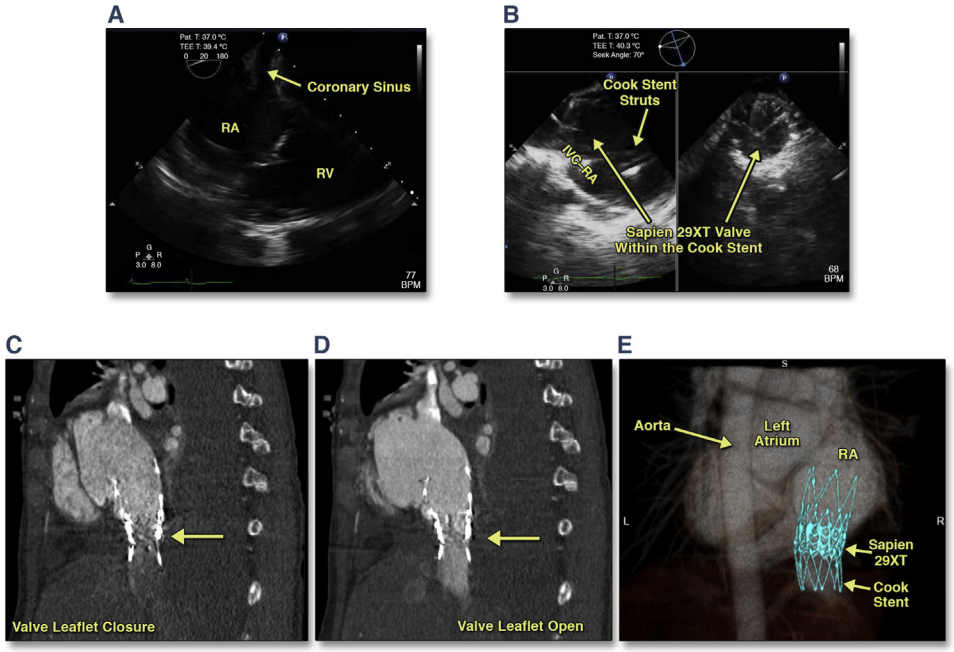
The height is taken between the right atrium–inferior vena cava (RA-IVC) junction plane **(A)** and the superior level of the first hepatic/accessory vein visualized **(B, C)** to assess for optimal valve positioning without hepatic vein obstruction. Sequential measurements are taken of the horizontal planes transecting the region 1 cm below the RA-IVC junction and 1 cm above the first identified hepatic vein for valve sizing **(D)**. Given the discrepancy in sizes between the larger RA-IVC plane tapering into the smaller hepatic vein plane, 3-dimensional (3D) printed models of the RA-IVC junction were made with SAPIEN 26XT and 29XT (Edwards Lifesciences Corp., Irvine, California) valve mockups inserted for fit testing. The SAPIEN 26XT valve demonstrated gaps between the IVC lining and the valve frame leading to concerns about perivalvular leak, and hence the SAPIEN 29XT valve was chosen **(E)**.

FIGURE 2 Simulating the Cardiac Catheterization Fluoroscopic Projection



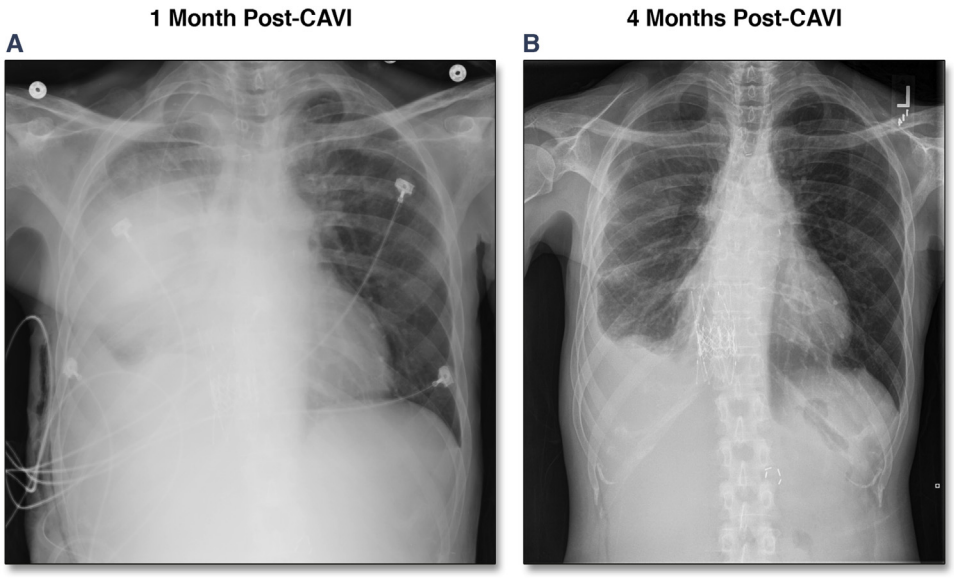
Volume-rendered inverted maximal intensity projection (MIP). **(A to D)** Apply MIP inversion and build the 3-dimensional volume image to include segmentation of the ribs, spine, right atrium (RA), right ventricle (RV), IVC, and first hepatic vein. Project this in black-and-white radiograph simulation. Restore original snapshots of the RA-IVC plane, and the IVC–hepatic vein plane separately into the 3-dimensional inverted volume MIP. Mark corresponding spinous processes in the coronal and sagittal views to the location of these respective planes: RA-IVC plane and the IVC–hepatic vein plane **(red line) (A, B)**. **(C, D)** C-arm angles: restore snapshot of the RA-IVC plane. Apply full crosshairs to the 3-dimensional image. Project the computed tomography (CT)– rendered anatomy in the 0°|0° anteroposterior (AP) view **(arrow)**. A multi-image snapshot cine clip taken from LAO0° → RAO50° of the CT-generated fluoroscopic projection gives the structural interventional team definition of landmark identification and separation in preparation for the catheterization lab (Online Video 1).

FIGURE 3 Periprocedural Multimodality Imaging: Role of Intraoperative TEE and Post-CAVI CT



(A, B) Intraprocedural TEE and post-CAVI 2-dimensional echocardiography and CT follow-up. The best intraprocedural TEE angles for CAVI cases are nontraditional views. To visualize the RA-IVC junction, start in a 4-chamber view and advance to the level of the coronary sinus (CS) **(A)**. Then, increase the probe angulation to bring the mouth of the IVC into plane **(B, left)**. TEE is critical in surveying the RA for thrombus, pericardial effusion (suggestive of right atrial posterior wall rupture), intraprocedure device migration, maintenance of CS flow, and potential paravalvular leak. Biplane across the RA-IVC junction demonstrates adequate valve positioning (**B,** Online Video 2). A 40-day post-procedure follow-up echocardiogram demonstrates pulsatile color Doppler flow across the CAVI valve (Online Video 3). **(C to E)** Post-CAVI follow-up CT scan obtained 5 days post-procedure. Cine loops through the axial and sagittal slices of the IVC demonstrate opening and closure of the SAPIEN XT valve (Edwards Lifesciences, Irvine, California) by the dynamic change in Hounsfield units across the valve and demonstration of no flow into the distal IVC with valve leaflet closure **(C)**, and flow with leaflet opening **(D)**. Three-dimensional volumetric CT reconstruction demonstrates clear positioning of the SAPIEN 29XT valve within the Cook stent (Cook Medical, Bloomington, Indiana) at the RA-IVC junction. CAVI = caval valve implantation; TEE = transesophageal echocardiography; other abbreviations as in **Figures 1 and 2**.

FIGURE 4 1-Month Post-CAVI Chest X-Ray and 4-Month Post-CAVI Chest X-Ray



(A) Post-CAVI, the patient was readmitted twice with recurring right-sided pleural effusions, transudative in nature, likely secondary to persistently increased right atrial pressures. **(B)** At 4-month follow-up, only small right-sided pleural effusions remained on the chest x-ray with no associated clinical symptoms.

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APPENDIX For supplemental tables and videos and their legends, please see the online version of this article.